

Investigation of different materials usage expediency for a low-rise public building from the energy efficiency standpoint

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Abstract. The purpose of this article is to identify the most preferable material on the assumption of the energy resources consumption reducing for buildings construction on the sustainable development criteria. The analysis of the energy resources costs for materials manufacture and their application for the low-rise public building structural construction was made. The use of structures, made of monolithic and precast reinforced concrete, ceramic brick, gas-concrete blocks, cellular concrete and polystyrene concrete, was considered. Energy costs were calculated for the following stages of the material life cycle: manufacturing, installation and operation. When calculating the energy costs for the material manufacturing, the raw materials extraction costs and the building material production costs for selected technology and equipment were taken into account. The construction costs include the material transporting costs and construction erection. The operating costs take into account equivalent heat losses through the enclosing structure made of the specified material. The calculation procedure assumes the energy costs summing up for each stage with the subsequent calculation of unit costs per 1 cub meter of the used material. To determine the total costs, the corresponding volumes were calculated. The calculation initial data are various estimate norms and other documents. On the basis of these calculations, the analysis of the energy costs required for the various types constructions erection in a low-rise public building was made. As a result, conclusions were drawn about the expediency of using different types materials for a given building in terms of the sustainable development concept.

1. Introduction

The constant growth of global environmental, social and economic problems in the context of the modern world globalization has become the reason for the formation, development and application of new states development strategies and theories. One of such strategies was the sustainable development concept, which was firstly discussed at the international conference in Stockholm in 1972.

This development strategy is designed to solve the urgent problems of mankind associated with the ecological deficit. Back in the 1970s, mankind passed the point at which the biological reserve, calculated as a difference between the Earth's biological capacity and the ecological trace, became



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zero [1]. Unfortunately, since that moment the world's population has consumed renewable resources faster than ecosystems can reproduce them, and throws more carbon dioxide into the atmosphere than ecosystems can absorb. A sustainable type of development presupposes the gradual restoration of natural ecosystems to a level that guarantees the environment stability, and one of the balance achieving means is energy efficiency.

The construction of energy efficient buildings and structures is one of the sustainable development concept directions. Energy efficiency is understood as characteristics reflecting the ratio of the useful effect from the energy resources use to the energy resources costs, produced in order to obtain such an effect, referring to products and technological processes. [2]

Energy-efficient buildings can be considered as various buildings for the erection, operation and demolition works of which the minimum possible quantity of different energy resources is spent. One of the simplest ways to reduce energy costs in the objects construction is using of low embodied energy building materials. Use of low embodied energy materials in buildings can greatly reduce the energy consumption in buildings and minimize the environmental impacts of building construction.

The total energy costs during construction also depend on the chosen structural scheme. The purpose of article is to identify the most preferable material on the assumption of the energy resources consumption reducing for buildings construction on the sustainable development criteria.

2. Description of calculation method

For building sector it is an important goal to produce buildings with minimum environmental impacts and from this point of view energy use is a central issue as enormous energy is used in the construction of buildings. The building sector is growing at a rapid pace and the present day buildings have become one of the largest consumer of fossil energy as industry and agriculture. [3]

In order to carry on energy resources calculations and study the obtained results, a low-rise public building, represented by the residential building of the rehabilitation center, was chosen. Because of the fact that the difference in the required energy resources depends on several various parameters, four different versions of the structural scheme with different supporting and enclosing structures made of different building materials were chosen for analysis. The first structural scheme of the building is represented by an incomplete frame, the supporting and enclosing structures of which are made of bricks with a thickness of 380 mm and 250 mm, respectively. The second structural scheme is an incomplete frame also, but some of the enclosing structures are made of gas concrete blocks with 300 mm thickness. The third one involves the construction of the residential building with longitudinal supporting walls made of monolithic reinforced concrete. The walls thickness is 160 mm. The last constructive scheme is a building with longitudinal supporting brick walls. The thickness of the supporting walls is 380 mm and the thickness of the self-supporting enclosing walls is 250 mm. The typical floor plan of the residential building for every structural schemes, described above, is shown in Figures 1-4.

To simplify and unify the calculations, the shape of the building typical floor in plain view was simplified to a rectangle. The number of staircase and elevator sections and windows, as well as their standard sizes, are assumed to be the same for all schemes under consideration.

The walls height of the floor is equal to 3.3 m. In calculations, the content of cement mortar in brickwork is assumed equal to 25 percent. The mortar content in the masonry, made of the gas concrete blocks is 13 percent. In order to simplify the data acquisition, some layers in the wall structure were not taken into account, such as: the interior wall surface finish and the exterior decoration of the enclosing structures with lime-sand mortar. The thickness of these layers is small enough, which explains the small difference in the materials volumes between different structural schemes, and, as a consequence, a small role in increasing or reducing the energy costs for the object erection.

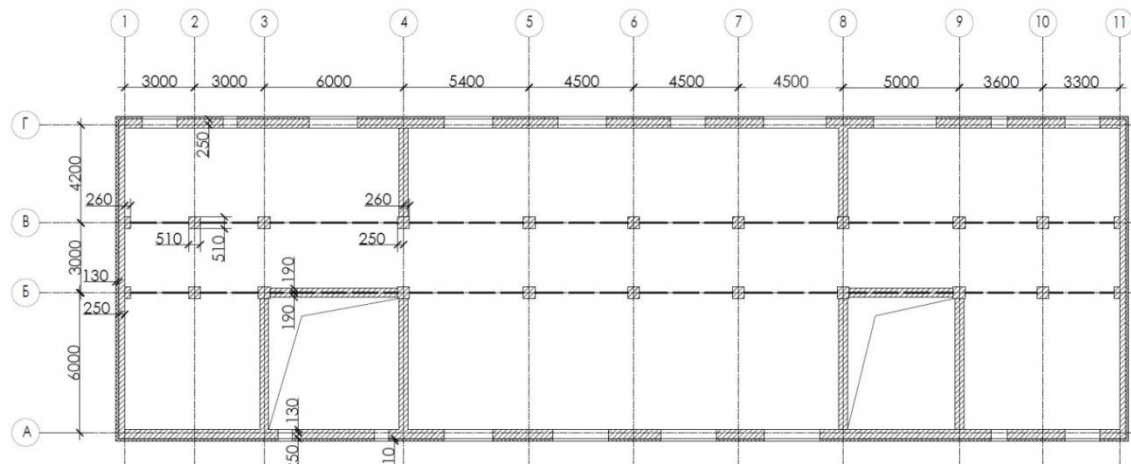


Figure 1. First structural scheme typical floor in plain view (incomplete frame, the supporting and enclosing structures are made of bricks)

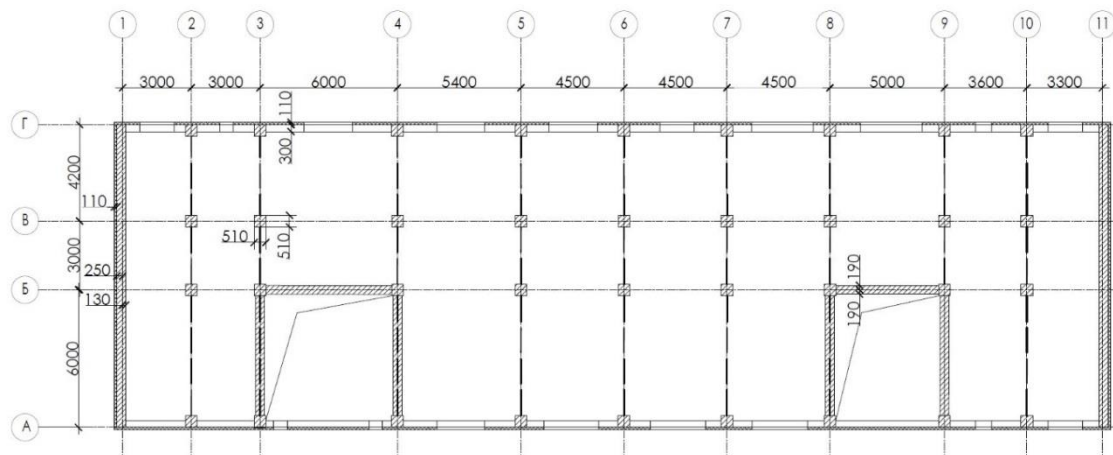


Figure 2. Second structural scheme typical floor in plain view (incomplete frame, enclosing structures are made of gas concrete blocks)

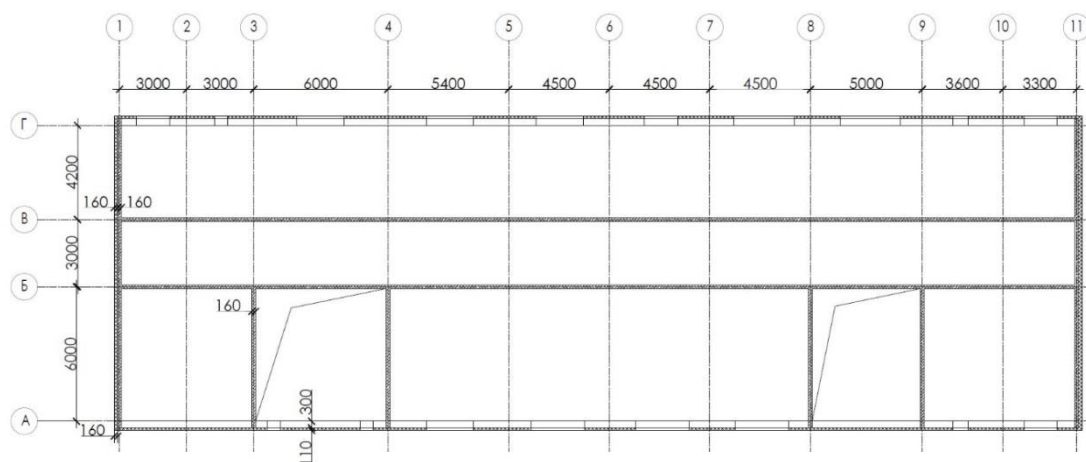


Figure 3. Third structural scheme typical floor in plain view (longitudinal supporting walls made of monolithic reinforced concrete)

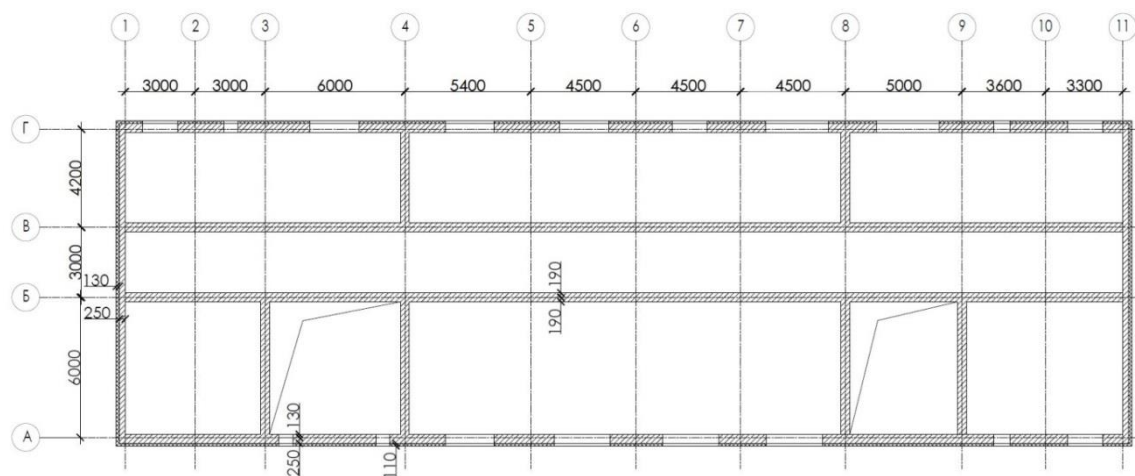


Figure 4. Fourth structural scheme typical floor in plain view (longitudinal supporting brick walls)

As a thermal insulation material mineral wool was used in all cases. The thickness of the effective thermal insulation was calculated in accordance with regulatory documents in force on the territory of the Russian Federation, taking into account the climatic characteristics of the construction area. [4] As a rehabilitation center erection place the Academicheskii microdistrict of Yekaterinburg, Sverdlovsk region, was chosen.

During the calculation, for each scheme, the building materials volumes, needed for erecting of load-bearing and enclosing structures of one standard floor were calculated, and then, based on the density of materials, the total masses of every building material for each structural scheme were calculated.

3. Analysis results

Embodied energy is a sum of all energy required to produce any goods or services, it is the energy consumed by all of the processes associated with the production of a building, from the acquisition of natural resources to product delivery, including mining, manufacturing of materials and equipment, transport and administrative functions. [5] The average values of embodied energy for chosen building materials characteristics and their densities are given in Table 1.

Table 1. Embodied energy and density for common building materials

Material	Density (kg/m ³)	Embodied energy (Mj/kg)
Brick	1700	3.00
In-site reinforced concrete	2500	1.90
Cement mortar	1500	1.33
Insulation rockwool	180	16.80
Gas concrete block	800	1.50

The characteristics indicated in the Table 1 were obtained on the basis of information, provided in various sources, namely: national standards for resource saving and energy conservation, operating in the territory of the Russian Federation, articles and scientific publications on building materials science and other open sources. These values are accepted as average ones, because of the fact that the

true density and embodied energy of each building material depends on many factors: the raw materials used, its quality characteristics, the selected production process technology, the transportation distance of the building material and other factors. [6], [7], [8]

The use of energy efficient alternative building technologies can result in considerable reduction in the embodied energy of the buildings. For all described earlier building materials, embodied energy was calculated for each of the four structural schemes based on the calculated volumes and the total weight. The obtained embodied energy values are presented in Table 2.

Table 2. Total volume and embodied energy for different structural schemes

Structural scheme number	Material	Total volume (m ³)	Embodied energy (Gj)
1	Brick	135.66	691.9
	Cement mortar	45.22	90.2
	Insulation rockwool	38.04	115.0
2	Brick	78.53	400.5
	Cement mortar	34.25	68.3
	Insulation rockwool	31.68	95.8
	Gas concrete block	60.02	72.0
3	Cement mortar	9.28	18.5
	Insulation rockwool	40.97	123.9
	Reinforced concrete	72.74	345.5
	Gas concrete block	62.10	74.5
4	Brick	203.05	1035.6
	Cement mortar	67.69	135.0
	Insulation rockwool	38.59	116.7

Summarizing the data for building materials, embodied energy was calculated for each of the four structural systems. The total embodied energy for each option is shown in Table 3.

Table 3. Total embodied energy for different structural schemes

Structural scheme number	Total embodied energy (Gj)
1	897.1
2	636.6
3	562.4
4	1287.3

According to the obtained results, from the energy efficiency and energy resources consumption standpoint the most expedient for the load-bearing and enclosing structures construction is the third structural scheme for erecting a building in which the load-bearing and part of the enclosing structures are made of in-situ reinforced concrete, and the remaining enclosing structures are built from gas concrete blocks. The least acceptable structural scheme is the last constructive scheme with load-bearing brick walls, which is connected with the initially larger materials volumes, used for

construction work than in the other considered schemes. Structural schemes with incomplete framework (number 1 and 2) are approximately equal.

4. Conclusion

Nowadays, the processes of buildings erection are highly energy intensive with a significant energy consumption right from the construction phase to the operation and maintenance ones. The total energy costs during construction depend on various factors, not only structural scheme and used materials.

There are a wide range of different methods to reduce the use of energy and other sources and one of them is using low embodied energy materials. The key message from this paper is that the detailed analysis of used materials and chosen structural scheme can help to meet the energy requirements for the building and correspond with the sustainable development concept directions.

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